1910

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

AN INVESTIGATION
OF THE
SAFETY AND ECONOMIC BENEFITS
OF
WATER-FILLED BUMPERS FOR VEHICLES

HOUSE RESOLUTION NO. 203

1968 LEGISLATIVE SESSION

MARCH 1969

69-26

69-26

STATE OF CALIFORNIA

RONALD REAGAN, *Governor*

BUSINESS AND TRANSPORTATION AGENCY

1120 N STREET, P.O. BOX 1139, SACRAMENTO 95805

AERONAUTICS
ALCOHOLIC BEVERAGE CONTROL
BANKING
CORPORATIONS
CALIFORNIA HIGHWAY PATROL
HOUSING AND COMMUNITY DEVELOPMENT
INSURANCE
MOTOR VEHICLES
PUBLIC WORKS
REAL ESTATE
SAVINGS AND LOAN

GORDON C. LUCE
Secretary

MARC SANDSTROM
Assistant Secretary

MERRITT E. VAN SANT
Assistant Secretary

March 30, 1969

Hon. Alan Short, Chairman
Senate Transportation Committee
State Capitol
Sacramento, California

Dear Alan:

Pursuant to the provisions of House Resolution No. 203 (Bear-1968), I am transmitting a report entitled "An Investigation of the Safety and Economic Benefits of Water-Filled Bumpers for Vehicles". This report has been reviewed and concurred with by the Department of General Services and the California Highway Patrol.

Sincerely,

GORDON C. LUCE, Secretary of
Business and Transportation

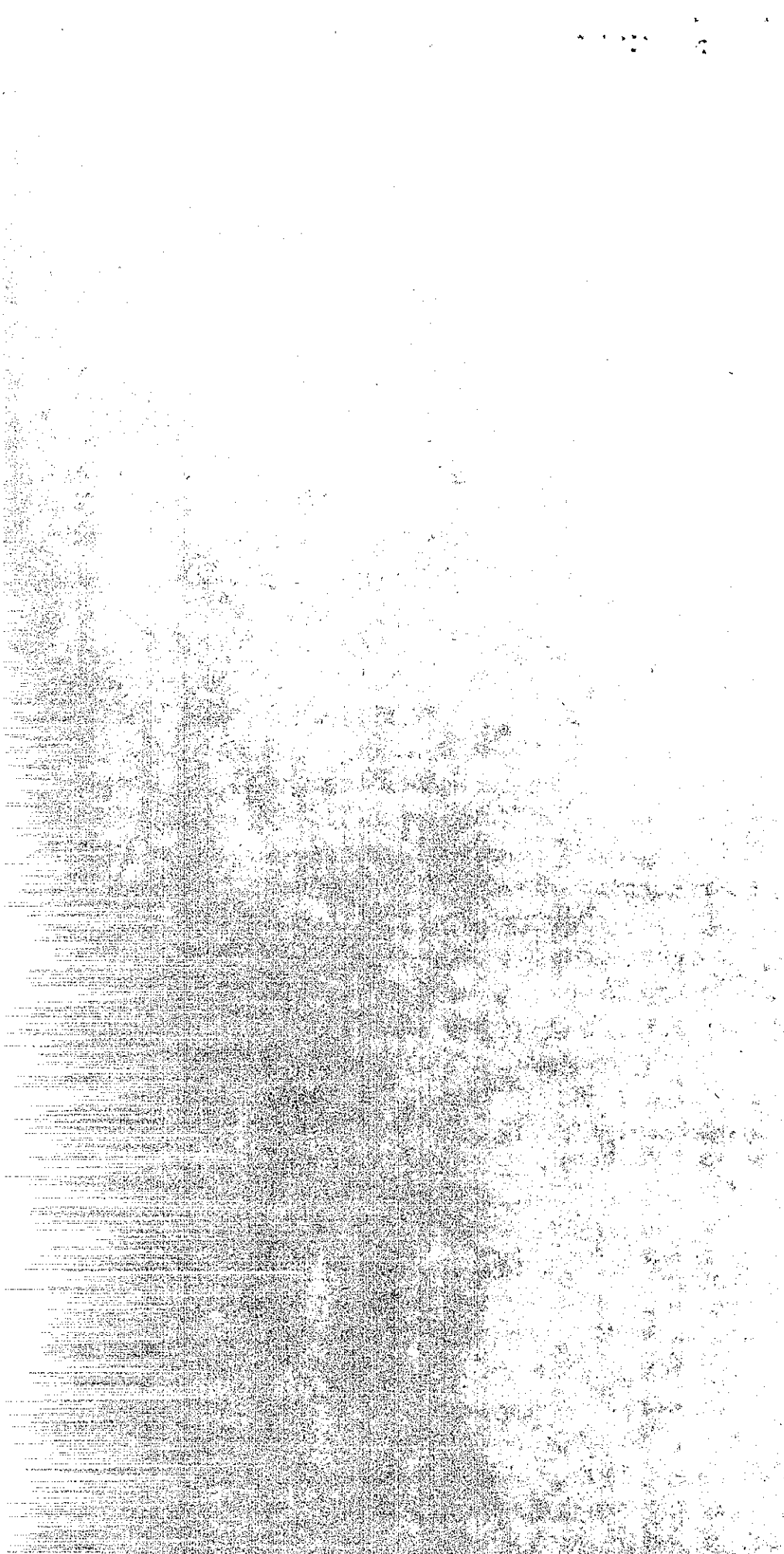
Attachment

cc: Hon. Ronald Reagan, Governor
Mr. Vernon J. Cristina
Mr. Robert E. Herdman
Mr. Fred C. Jennings
Mr. Moon Lim Lee
Mr. Alexander H. Pope
Mr. V. Earl Roberts
Mr. William S. Whitehurst

SIMILAR LETTER SENT TO:

Hon. James D. Driscoll
Hon. C. D. Alexander
Hon. John F. Foran

Mr. James A. Moe
Mr. H. S. Fenton
Mr. E. W. Rhyner
Mr. J. A. Legarra
Mr. Sam Helwer
Mr. D. L. Wieman
Mr. J. T. Kassel
Mr. R. T. Martin
Mr. G. A. Hill
Mr. S. H. Lathrop
Mr. C. G. Beer



STATE OF CALIFORNIA

RONALD REAGAN, Governor

BUSINESS AND TRANSPORTATION AGENCY

1120 N STREET, P.O. BOX 1139, SACRAMENTO 95805

AERONAUTICS
ALCOHOLIC BEVERAGE CONTROL
BANKING
CORPORATIONS
CALIFORNIA HIGHWAY PATROL
HOUSING AND COMMUNITY DEVELOPMENT
INSURANCE
MOTOR VEHICLES
PUBLIC WORKS
REAL ESTATE
SAVINGS AND LOAN

GORDON C. LUCE
Secretary

MARC SANDSTROM
Assistant Secretary

MERRITT E. VAN SANT
Assistant Secretary

March 30, 1969

Hon. C. D. Alexander
Secretary of the Senate
State Capitol
Sacramento, California

Dear Mr. Alexander:

Pursuant to the provisions of House Resolution No. 203 (Bear-1968), I am transmitting a report entitled "An Investigation of the Safety and Economic Benefits of Water-Filled Bumpers for Vehicles." This report has been reviewed and concurred with by the Department of General Services and the California Highway Patrol.

Sincerely,

GORDON C. LUCE, Secretary of
Business and Transportation

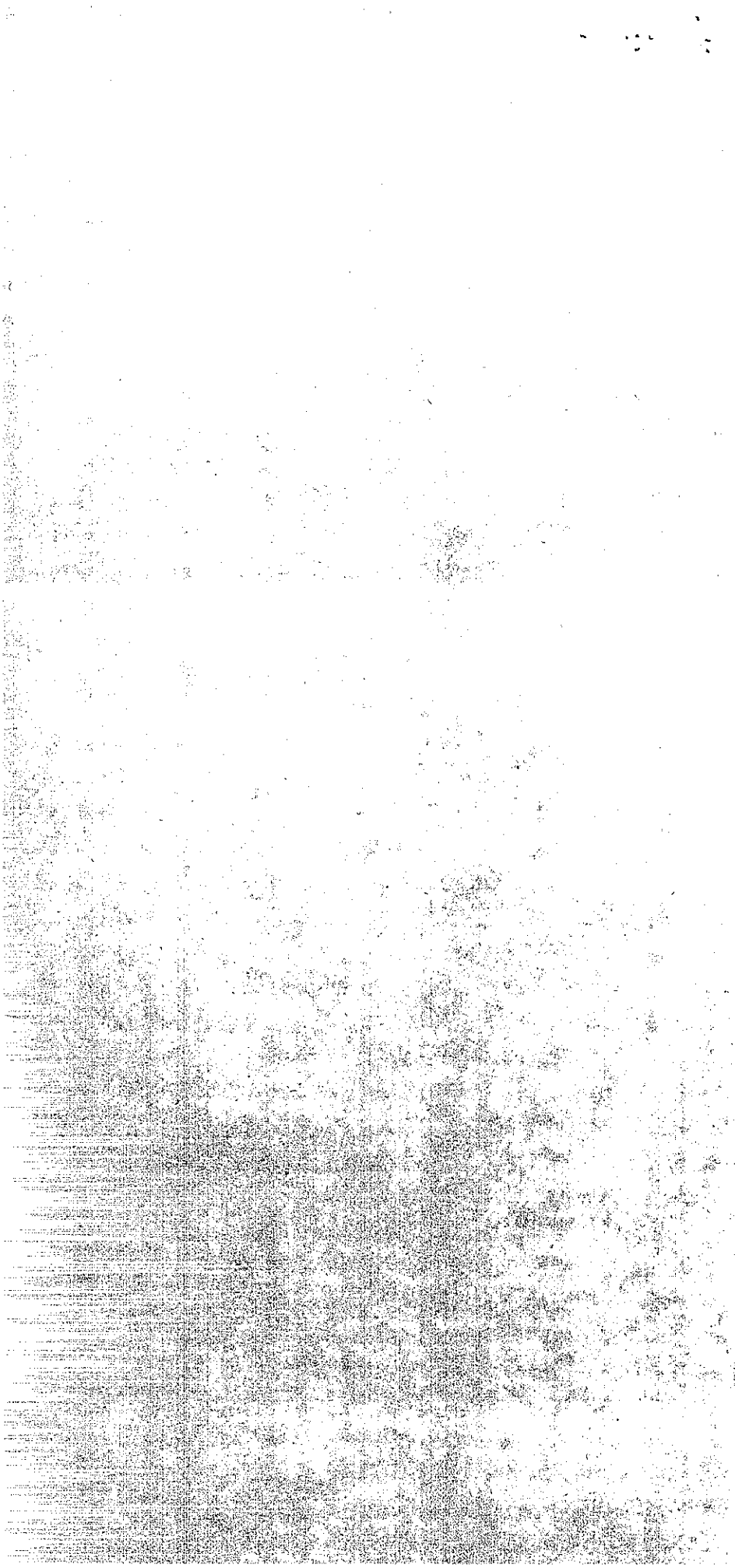
Attachment

cc: Hon. Ronald Reagan, Governor
Mr. Vernon J. Cristina
Mr. Robert E. Herdman
Mr. Fred C. Jennings
Mr. Moon Lim Lee
Mr. Alexander H. Pope
Mr. V. Earl Roberts
Mr. William S. Whitehurst

SIMILAR LETTER SENT TO:

Hon. James D. Driscoll
Hon. Alan Short
Hon. John F. Foran

Mr. James A. Moe
Mr. H. S. Fenton
Mr. E. W. Rhyner
Mr. J. A. Legarra
Mr. Sam Helwer
Mr. D. L. Wieman
Mr. J. T. Kassel
Mr. R. T. Martin
Mr. G. A. Hill
Mr. S. H. Lathrop
Mr. C. G. Beer



STATE OF CALIFORNIA

RONALD REAGAN, Governor

BUSINESS AND TRANSPORTATION AGENCY

1120 N STREET, P.O. BOX 1139, SACRAMENTO 95805

AERONAUTICS
ALCOHOLIC BEVERAGE CONTROL
BANKING
CORPORATIONS
CALIFORNIA HIGHWAY PATROL
HOUSING AND COMMUNITY DEVELOPMENT
INSURANCE
MOTOR VEHICLES
PUBLIC WORKS
REAL ESTATE
SAVINGS AND LOAN

GORDON C. LUCE
Secretary

MARC SANDSTROM
Assistant Secretary

MERRITT E. VAN SANT
Assistant Secretary

March 30, 1969

Hon. John F. Foran, Chairman
Assembly Transportation Committee
State Capitol
Sacramento, California

Dear John:

Pursuant to the provisions of House Resolution No. 203 (Bear - 1968), I am transmitting a report entitled "An Investigation of the Safety and Economic Benefits of Water-Filled Bumpers for Vehicles." This report has been reviewed and concurred with by the Department of General Services and the California Highway Patrol.

Sincerely,

GORDON C. LUCE, Secretary of
Business and Transportation

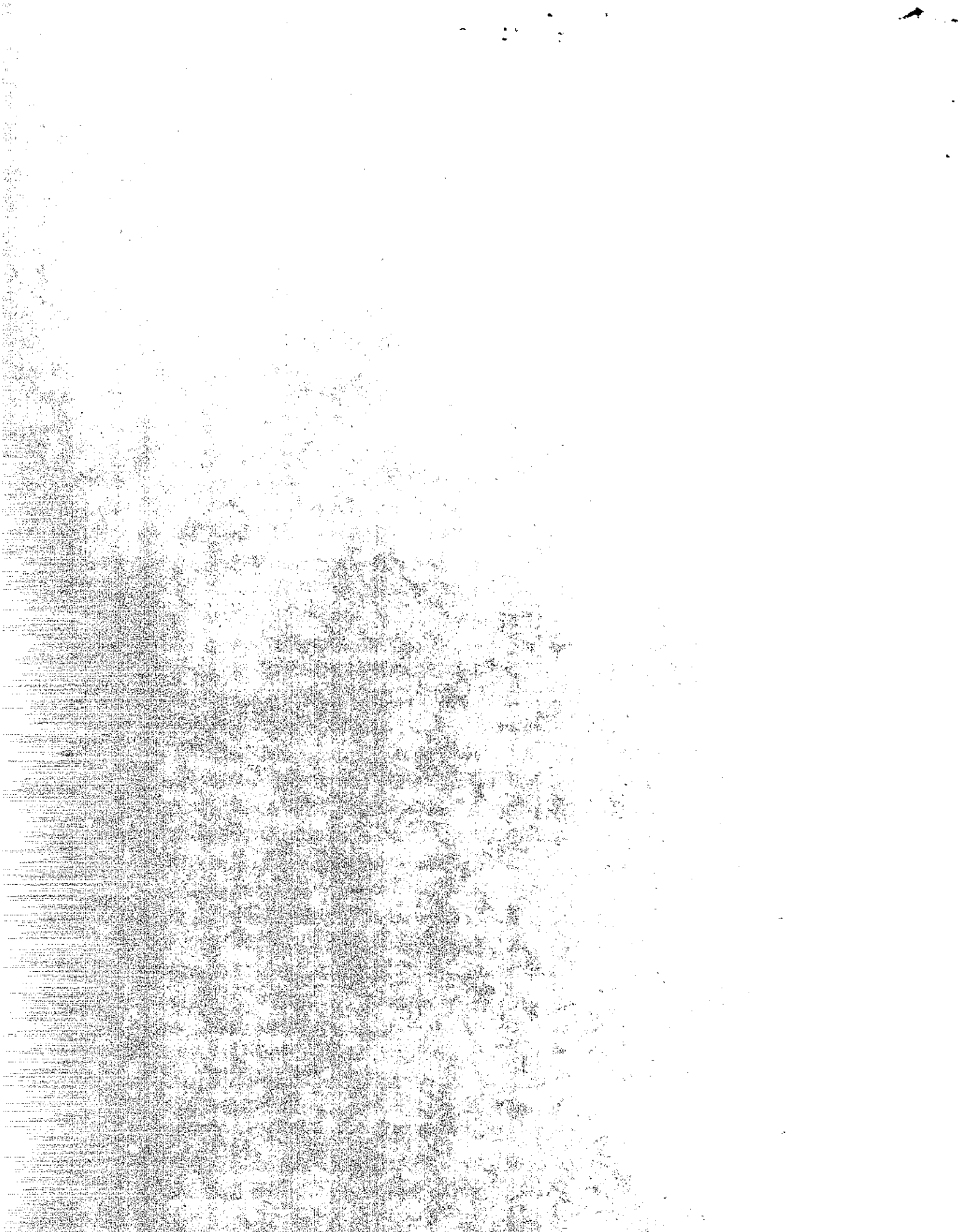
Attachment

cc: Hon. Ronald Reagan, Governor
Mr. Vernon J. Cristina
Mr. Robert E. Herdman
Mr. Fred C. Jennings
Mr. Moon Lim Lee
Mr. Alexander H. Pope
Mr. V. Earl Roberts
Mr. William S. Whitehurst

SIMILAR LETTER SENT TO:

Hon. James D. Driscoll
Hon. C. D. Alexander
Hon. Alan Short

Mr. James A. Moe
Mr. H. S. Fenton
Mr. E. W. Rhyner
Mr. J. A. Legarra
Mr. Sam Helwer
Mr. D. L. Wieman
Mr. J. T. Kassel
Mr. R. T. Martin
Mr. G. A. Hill
Mr. S. H. Lathrop
Mr. C. G. Beer



STATE OF CALIFORNIA

RONALD REAGAN, Governor

BUSINESS AND TRANSPORTATION AGENCY

1120 N STREET, P.O. BOX 1139, SACRAMENTO 95805

AERONAUTICS
ALCOHOLIC BEVERAGE CONTROL
BANKING
CORPORATIONS
CALIFORNIA HIGHWAY PATROL
HOUSING AND COMMUNITY DEVELOPMENT
INSURANCE
MOTOR VEHICLES
PUBLIC WORKS
REAL ESTATE
SAVINGS AND LOAN

GORDON C. LUCE
Secretary

MARC SANDSTROM
Assistant Secretary

MERRITT E. VAN SANT
Assistant Secretary

March 30, 1969

Hon. James D. Driscoll
Chief Clerk of the Assembly
State Capitol
Sacramento, California

Dear Mr. Driscoll:

Pursuant to the provisions of House Resolution No. 203 (Bear - 1968), I am transmitting a report entitled "An Investigation of the Safety and Economic Benefits of Water-Filled Bumpers for Vehicles." This report has been reviewed and concurred with by the Department of General Services and the California Highway Patrol.

Sincerely,

GORDON C. LUCE, Secretary of
Business and Transportation

Attachment

cc: Hon. Ronald Reagan, Governor
Mr. Vernon J. Cristina
Mr. Robert E. Herdman
Mr. Fred C. Jennings
Mr. Moon Lim Lee
Mr. Alexander H. Pope
Mr. V. Earl Roberts
Mr. William S. Whitehurst

SIMILAR LETTER SENT TO:

Hon. C. D. Alexander
Hon. Alan Short
Hon. John F. Foran

Mr. James A. Moe
Mr. H. S. Fenton
Mr. E. W. Rhyner
Mr. J. A. Legarra
Mr. Sam Helwer
Mr. D. L. Wieman
Mr. J. T. Kassel
Mr. R. T. Martin
Mr. G. A. Hill
Mr. S. H. Lathrop
Mr. C. G. Beer

STATE OF CALIFORNIA

RONALD REAGAN, *Governor*

BUSINESS AND TRANSPORTATION AGENCY

1120 N STREET, P.O. BOX 1139, SACRAMENTO 95805

AERONAUTICS
ALCOHOLIC BEVERAGE CONTROL
BANKING
CORPORATIONS
CALIFORNIA HIGHWAY PATROL
HOUSING AND COMMUNITY DEVELOPMENT
INSURANCE
MOTOR VEHICLES
PUBLIC WORKS
REAL ESTATE
SAVINGS AND LOAN

GORDON C. LUCE
Secretary

MARC SANDSTROM
Assistant Secretary

MERRITT E. VAN SANT
Assistant Secretary

March 30, 1969

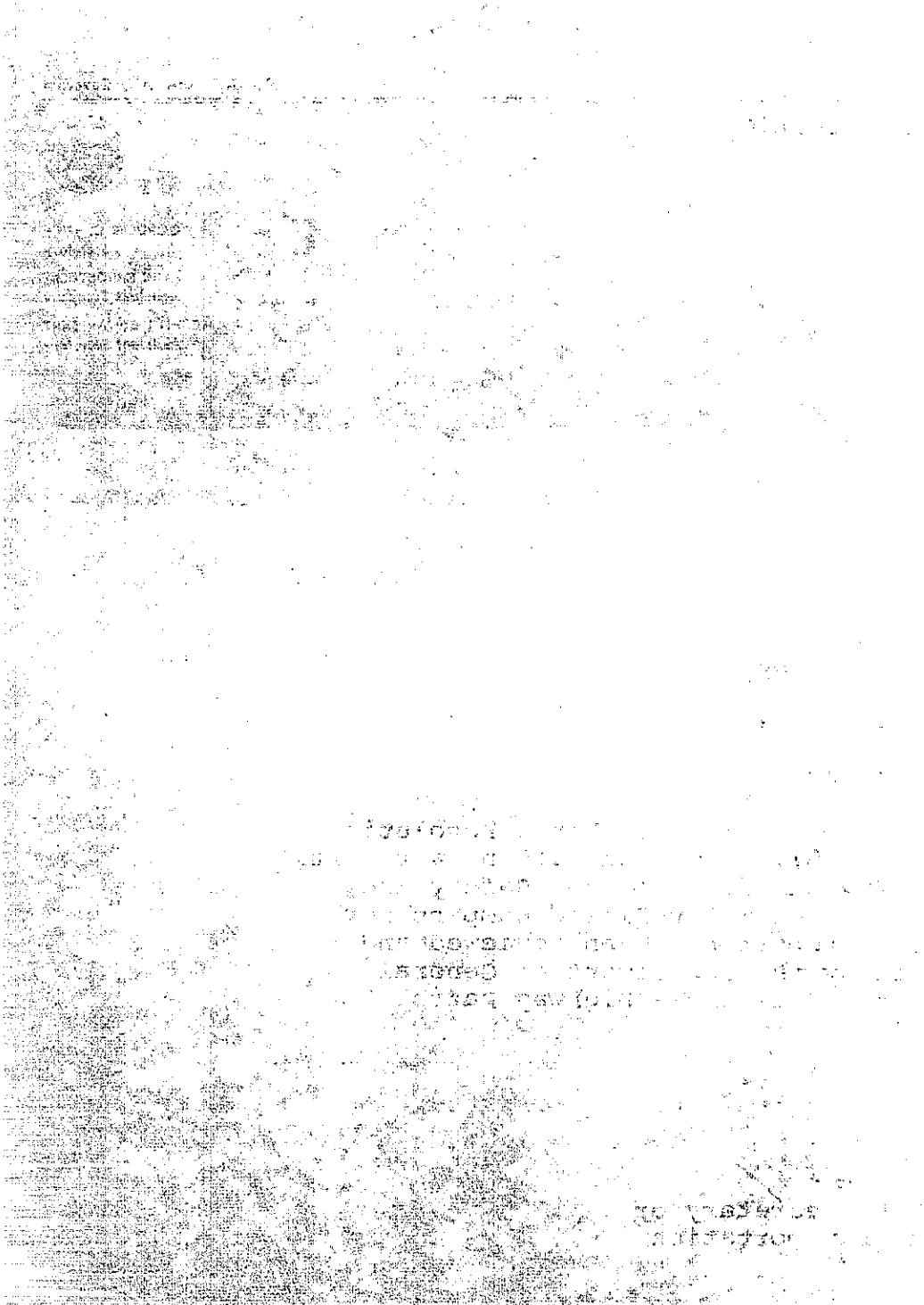
Hon. C. D. Alexander
Secretary of the Senate
State Capitol
Sacramento, California

Dear Mr. Alexander:

Pursuant to the provisions of House Resolution No. 203 (Bear-1968), I am transmitting a report entitled "An Investigation of the Safety and Economic Benefits of Water-Filled Bumpers for Vehicles." This report has been reviewed and concurred with by the Department of General Services and the California Highway Patrol.

Sincerely,

GORDON C. LUCE, Secretary of
Business and Transportation



STATE OF CALIFORNIA

RONALD REAGAN, Governor

BUSINESS AND TRANSPORTATION AGENCY

1120 N STREET, P.O. BOX 1139, SACRAMENTO 95805

AERONAUTICS
ALCOHOLIC BEVERAGE CONTROL
BANKING
CORPORATIONS
CALIFORNIA HIGHWAY PATROL
HOUSING AND COMMUNITY DEVELOPMENT
INSURANCE
MOTOR VEHICLES
PUBLIC WORKS
REAL ESTATE
SAVINGS AND LOAN

GORDON C. LUCE
Secretary

MARC SANDSTROM
Assistant Secretary

MERRITT E. VAN SANT
Assistant Secretary

March 30, 1969

Hon. James D. Driscoll
Chief Clerk of the Assembly
State Capitol
Sacramento, California

Dear Mr. Driscoll:

Pursuant to the provisions of House Resolution No. 203 (Bear - 1968), I am transmitting a report entitled "An Investigation of the Safety and Economic Benefits of Water-Filled Bumpers for Vehicles." This report has been reviewed and concurred with by the Department of General Services and the California Highway Patrol.

Sincerely,

GORDON C. LUCE, Secretary of
Business and Transportation

Attachment

1968 Legislative Session

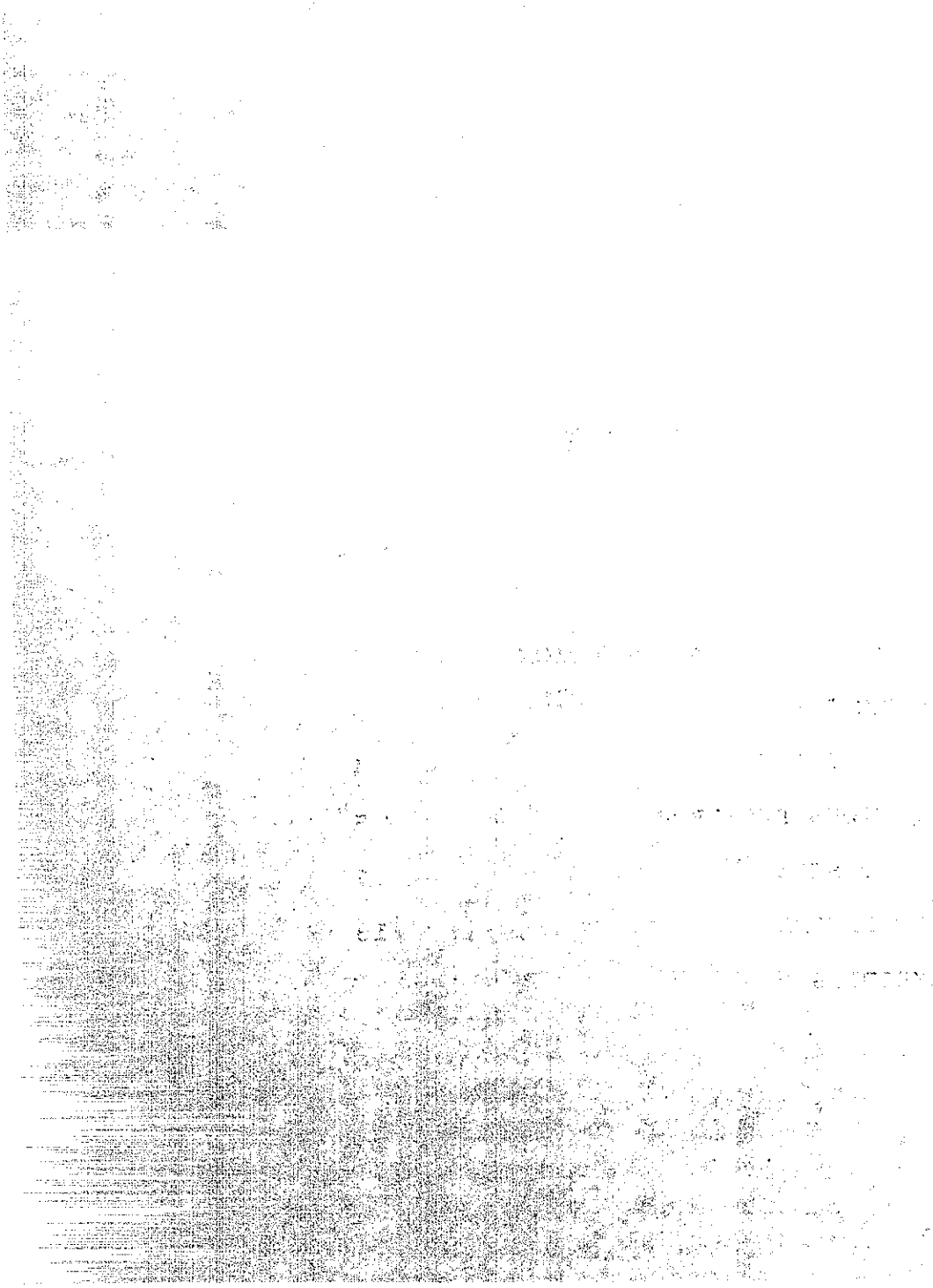
HOUSE RESOLUTION NO. 203

Relating to Water-Filled Safety Devices for Vehicles and Freeways

Resolved by the Assembly of the State of California, that the Transportation Agency, in cooperation with the Department of General Services, is requested to conduct an investigation concerning the safety and economic benefits of water-filled bumpers for vehicles and water-filled barriers for obstacles adjacent to freeways, with reference to be made, to the greatest extent possible, to research efforts being done by other agencies concerning these subjects; and be it further Resolved, That the Transportation Agency, in cooperation with the Department of General Services, is requested to prepare and submit a preliminary report to the Legislature no later than March 30, 1969, concerning the results of the investigation conducted, including in its report the feasibility of putting water-filled bumpers on State-owned vehicles.

TABLE OF CONTENTS

		Page
I.	BACKGROUND - INTRODUCTION	1
II.	OBJECTIVE	3
III.	CONCLUSIONS	4
IV.	PREVIOUS RESEARCH	5
V.	DISCUSSION	7
VI.	REFERENCES	13
VII.	EXHIBITS	



I. BACKGROUND - INTRODUCTION

In 1968 the Assembly of the State of California passed House Resolution No. 203. This resolution requested, in part, that the Transportation Agency, in cooperation with the Department of General Services, conduct an investigation concerning the safety and economic benefits of water-filled bumpers for vehicles and submit a report of this investigation to the Legislature no later than March 30, 1969. This report was to include the feasibility of installing these water-filled bumpers on State-owned vehicles. The Resolution placed special emphasis on evaluating whatever research had already been accomplished by other agencies.

The findings reported herein were determined from a review of the results of testing and research conducted by the water-filled bumper manufacturer and by Brigham Young University, under contract to the manufacturer; a mail survey of current users of water-filled bumpers; and a review of recent accident data on State-owned vehicles.

The water-filled bumper consists of a hollow vinyl plastic molded shell that is attached to a fiberglass coated plywood beam. This assembly is in turn attached to the frame of the vehicle, replacing the steel bumper. The interior of the shell is separated by baffles, thus creating multiple chambers. The thickness of the shell wall is 1/4". Holes are drilled in the top face of the plastic bumper and tethered plastic stoppers are inserted in these holes. When the plastic bumper comes in contact with another object, impact energy is absorbed by elastically deforming the bumper, ejecting the plastic stoppers, and forcing water out of the bumper. After the impact force is removed, the bumper returns to its original shape but must be refilled with water and the plastic stoppers must be reinserted. Special bumper jack attachments are included with the purchase of the bumpers. Provisions for trailer hitches can also be made. The bumpers are painted to match, or contrast with, the color of the vehicle. Please see Figure 1 on the following page for an example of the appearance of an installed plastic bumper.

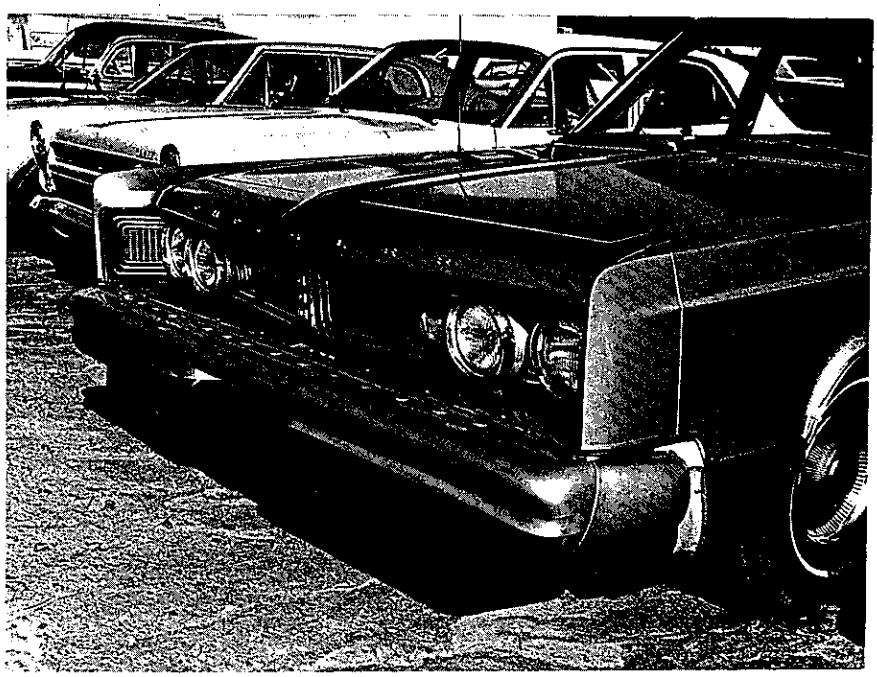


FIGURE 1

II. OBJECTIVE

The objective of this study was to conduct an investigation concerning the safety and economic benefits of water-filled bumpers for vehicles, including the feasibility of putting water-filled bumpers on State-owned vehicles, with reference made, to the greatest extent possible, to research accomplished by other agencies.

III. CONCLUSIONS

The conclusions of this investigation are as follows:

1. The water-filled bumper generally will prevent occupant injury and vehicular damage when complete bumper-to-bumper contact with identical vehicles, both equipped with water-filled bumpers, occurs at relative velocities of approximately 15 mph or less, ideal conditions which would rarely all be present in any given collision.

2. The water-filled bumper's effectiveness is very much dependent on the relative velocities at impact, the angle and point of impact, the relative heights of the bumpers if bumper-to-bumper contact occurs, and the width of the bumper contacted during an impact.

3. There may be some reduction in vehicular damage and occupant injury with the use of water-filled bumpers in "fender bender" type collisions in heavy traffic on urban streets.

4. In collisions at speeds and other conditions encountered on highways, it is unlikely that water-filled bumpers will result in any significant reduction in vehicular damage or occupant injury.

5. Based on the data and information available at this time, it appears that the installation of water-filled bumpers on State-owned vehicles is not economically feasible. The primary factors considered included the effects on safety, public liability and property damage insurance, recent statistics of accident repair costs for State-owned vehicles, and the anticipated accident severity reduction that might be effected through the use of water-filled bumpers on State-owned vehicles.

IV. PREVIOUS RESEARCH

Research on the effectiveness of water-filled bumpers has been accomplished at Brigham Young University, under contract to the manufacturer, John Rich Enterprises, Inc., of Sacramento, California, and by the manufacturer himself.

The initial testing was reported by B.Y.U. in December 1967[1]. The research objective for this 1967 test series was to evaluate the performance limits of the then current water-filled bumper design. The test series consisted of 28 full scale automobile rear-end collisions and one broadside collision. This test series included 11 full scale tests by the manufacturer at his facilities in Sacramento. The test vehicles were chosen to be as nearly identical as possible. The tests were conducted at impact speeds of between 6 and 21 mph with the impacted vehicle stationary, its transmission disengaged, and its brakes released. The impacting vehicle was driven by a live driver. There were no occupants in the impacted vehicle.

Electronic and photographic techniques were employed to measure the vehicular decelerations and accelerations and record the vehicular damage. Standard domestic vehicles of 1956-1960 vintage were used. Vehicle weights varied from 2608 lbs. (1960 compact sedan) to 3955 lbs. (1959 standard sedan).

The results of this B.Y.U. testing (6-21 mph) indicated that the deceleration was milder with plastic-to-plastic bumper impacts than with steel-to-steel bumper impacts. Jerk, or rate of onset of acceleration, was reduced. This may well be the most significant finding of this study because jerk is a major factor in creating whiplash injury during a rear-end collision. The installation of the plastic bumper on the impacted vehicle only also provided an improvement over steel-to-steel bumper impacts. It was concluded in the B.Y.U. report that a relative velocity of 15 mph was the maximum speed at which plastic-to-steel bumper impacts could be sustained with no measurable sheet metal damage. This so-called "damage threshold" for plastic-to-plastic bumper impacts was about 17-19 mph. A weakness in the backup support for the water-filled bumper was noted during several of these tests. It was concluded in the 1967 B.Y.U. report that for rear-end collisions at velocities of up to 20 mph, plastic bumpers on both vehicles will provide significant protection against whiplash and other impact related injuries for the occupants of both vehicles if conventional lap belt restraint systems are used. At speeds greater than 20 mph, the plastic bumper's effectiveness would be dependent on the details of the particular collision.

A second test series was reported in January 1969[2]. This testing was also accomplished at Brigham Young University under contract to John Rich Enterprises, Inc., and was conducted to reevaluate the plastic bumper's effectiveness by employing improved experimental techniques. For this test series, identical 1966 standard sedans weighing 3830 lbs. were used as test vehicles. The test conditions, with the exception of the vehicular speeds, were identical to those utilized for the B.Y.U. 1967 test series. Impact velocities in the second test series varied between 4 and 15 mph for the 9 tests that were conducted. It was stated by B.Y.U. that a 50% reduction in occupant loadings would be realized for a rear-end collision at 10 mph if both vehicles were equipped with plastic bumpers. (It is obvious that this effectiveness will decrease as relative impact velocities increase.)

It was concluded by B.Y.U. that in impacts of two standard sedans, both equipped with plastic bumpers, at speeds below 20 mph, injury hazards can be cut in half and hazards of economic loss can be greatly reduced. Each configuration tested that involved the use of one or two plastic bumpers showed a reduction in occupant and vehicle loads and in vehicle damage when compared to steel-to-steel bumper impacts at the same speeds. Threshold velocities for significant vehicle damage were reported as 12, 9, and 5 mph respectively for plastic-to-plastic, steel-to-plastic, and steel-to-steel bumper impacts. It was further concluded by B.Y.U. that the presence of plastic bumpers can provide a significant extra margin of safety that could possibly spell the difference between injury and no injury and/or damage and no damage in many rear-end collisions.

V. DISCUSSION

The performance of the water-filled plastic bumper is greatly influenced by the configurations and relative heights of the bumpers on the impacting vehicles in rear-end or headon collisions. This was made evident in testing described in the B.Y.U. 1967 report when for several tests the vehicular damage incurred was dependent on the relative bumper heights. For many of these tests, the bumper heights were adjusted to match. In one instance, this adjustment significantly decreased the vehicular damage sustained. It was reported in the B.Y.U. 1969 report that a mismatch in the bumper height of the "identical" vehicles contributed significantly to the $200 damage estimate for the two vehicles (both equipped with plastic bumpers) at an impact velocity of 14.8 mph. As a basis of comparison, a 10 mph impact with steel-to-steel bumper contact resulted in a $150 damage estimate. A 12.6 mph steel-to-plastic bumper impact also resulted in a $150 damage estimate. According to the manufacturer, plastic bumpers are positioned at an approximate height of 21 inches whenever possible. However, until bumper heights are standardized as recommended by the Society of Automotive Engineers[3], identical bumper heights on all vehicles cannot be assured (see Exhibit 1). The SAE proposed standard also includes provisions to control the shape and configuration of vehicular bumpers. This is also necessary if good bumper-to-bumper contact is to be obtained. Impacts with some current projecting type bumper designs provide little more than point contact until the bumper structure collapses.

All of the B.Y.U. testing, with the exception of one test, was of the rear-end type that provides relatively "square" bumper-to-bumper contact. Although B.Y.U. stated that about 35% of all 1967 motor vehicle accidents were rear-end collisions[2], only 24% of the 1967-68 fiscal year accidents involving State-owned vehicles were rear-end accidents[4,5].

The test procedure used at B.Y.U. included a disengaged transmission and released brakes on the stationary vehicle. Although relative damage in plastic-to-plastic, steel-to-plastic, and steel-to-steel bumper impacts was valid using this procedure, accident severity was decreased due to the "free wheeling" condition of the impacted vehicle.

Another significant deviation from most actual collisions was the absence of braking of the impacting vehicle. The application of brakes, plus the weight of the water-filled bumper (estimated net increase of 95 lbs. per bumper) at the extremities

of the vehicle, will likely accentuate the tendency of the front of the impacting vehicle to dive, thereby significantly decreasing the height of its front bumper.

It was stated in the 1967 B.Y.U. report that inadequate bumper support was observed in the vehicle structure in at least two plastic-to-plastic bumper tests, one at 19 mph and the other at 18 mph. This indicates that, even in cushioned plastic-to-plastic bumper impacts of 19 mph and less into a stationary vehicle, the impact forces involved may be beyond the yield point of portions of the frames of relatively new vehicles. This also is an indication of the very limited effectiveness of the plastic bumper, or any bumper, when high speed impacts occur.

The total cost to equip all State-owned automobiles and trucks as of December 1, 1968, would be $3,153,700. This is based on equipping 14,755 autos with two plastic bumpers each at $50 per bumper and 13,985 trucks with two plastic bumpers each at $60 per bumper. The number of vehicles was obtained from Department of Motor Vehicle Reports[6,7]. The cost of the bumpers was obtained as a firm quote from Mr. John Rich, President of the firm that manufacturers and installs the plastic bumpers.

The Department of General Services contacted the State's current insurance carrier and was informed that the State would receive no insurance rate reduction if water-filled bumpers were installed on State-owned vehicles. Thus, the State's cost for public liability and property damage insurance would not be reduced, at least until there is more substantial evidence to show that a reduction would be warranted. An immediate savings that might be realized by installing plastic bumpers on State-owned vehicles would be the reduction of repair costs of the State-owned vehicles. The estimated average repair cost per accident for the State-owned vehicle involved is $150. This is based on repair cost figures for the Division of Highways during the 1966 calendar year. The total number of accidents involving State-owned vehicles for the most recent completed 12 month period on record (July 1, 1967, through June 30, 1968) was 3,520[3,4]. Using these figures, the total estimated annual repair cost for State-owned vehicles is $528,000. The maximum possible benefit-cost ratio for plastic bumper installation, assuming a 5-year average life for the State-owned vehicle, is thus only [(5) ($528,000) ÷ ($3,153,700)] = 0.84. Since this figure is based on the assumption that all the repair costs to the State could be eliminated, a more realistic assumption of the effect of using plastic bumpers would be a decrease in repair costs of 10%, which reduces the benefit-cost ratio to 0.084.

Another method of analysis that amortizes the cost of the plastic bumpers over the vehicle life was also completed. This second method consisted of calculating the probable accidents per vehicle. Using the 1967-68 fiscal year accident frequency of

12.07 per million miles driven in State-owned vehicles[3,4], the average vehicle retirement mileage of 85,000 miles and an estimated average repair cost of $150 per accident for State vehicles, the average accident repair cost per State-owned vehicle was found to be (85,000 ÷ 1,000,000)(12.07)($150) = $154. The cost of furnishing and installing two bumpers is $100 for an automobile and $120 for a truck. Using this analysis, the current accident repair cost for State-owned vehicles would have to be reduced by $100 ÷ $154 = .65 or 65% for automobiles and even more (78%) for trucks to pay for the plastic bumper installation. A reduction of this magnitude in repair costs is highly unlikely as only a 50% reduction was estimated in the B.Y.U. 1969 report for ideal collision conditions.

These economic analyses have been made on the premise that one set of plastic water-filled bumpers will last for the full service life of the vehicle (approximately 5 years or 85,000 miles). At the present time, we do not have operational evidence that would indicate that the plastic bumpers are capable of resisting impact damage and exposure to the weather for that length of time. If they do not, then it would be necessary to base any analysis on at least two sets of bumpers over the service life of the vehicle.

Another factor to consider in estimating any reduction of accident repair costs is the number of accidents in which the plastic bumper may be effective. A summary of the accident types involving State-owned vehicles is shown in Table 1 (see next page).

It is estimated that the plastic bumpers may affect the accident severity in no more than 60% of these accidents. The accident severity reduction attributable to the use of plastic bumpers in these accidents would probably vary from very significant in the relatively minor, backing type of accident to quite insignificant in accidents that are more severe or that do not conform to the "ideal collision" conditions previously discussed.

Another factor to consider is the probability of the other vehicle being equipped with water-filled plastic bumpers when collision with another vehicle occurs. If the entire fleet of State-owned vehicles were equipped with plastic bumpers, this would still account for only 0.3% of all the trucks and automobiles registered in California as of December 1, 1968. We estimate that much less than 1% of the vehicles registered in California are now equipped with water-filled bumpers. Consequently, the probability of a plastic bumper-to-plastic bumper impact, the most effective in decreasing personal injury and property damage is extremely low at this time.

Another factor to consider is the increase in vehicular weight that is realized when water-filled plastic bumpers are

TABLE I

	July 1 - Dec. 31 1967	Jan. 1 - June 30 1968	Total
A. COLLISION WITH OTHER VEHICLE			
1. Hit other vehicle in rear	192	179	371*
2. Hit from the rear	222	236	458*
3. While passing	50	116	166
4. While being passed	51	103	154
5. From an angle	273	280	553
6. Head-on collision	26	106	132*
7. While backing	103	126	229*
8. Miscellaneous	64	70	134*
Total Collision With Other Vehicle			2197
B. SOLO ACCIDENT			
1. Ran off road - lost control	122	109	231
2. Ran off road - evasively	41	37	78
3. Collided with stationary object	141	162	303*
4. Hit an animal	30	32	62*
5. Run away	20	37	57
6. While backing	112	183	295*
7. Miscellaneous	32	49	81*
Total Solo Accidents			1107
C. STRIKING PEDESTRIAN			
1. In crosswalk	3	2	5
2. Not in crosswalk	3	10	13
3. Other	3	3	6
Total Pedestrian Accidents			24
D. MISCELLANEOUS			
1. Vandalism	6	13	19
2. Fire	6	2	8
3. Other	80	85	165
Total Miscellaneous			192
		TOTAL	3520

*Plastic bumper may decrease accident severity.

utilized. The weight of the full water bumper is approximately 135 lbs. The estimated weight of an average steel bumper is 40 lbs. Thus a net increase of 95 lbs. per bumper, or 190 lbs. per vehicle, is realized. This weight, at the vehicle extremities, will inevitably alter the vehicle's handling characteristics to some degree. The replies to the mail questionnaire indicated that in some cases handling was improved whereas in other cases detrimental effects were experienced. In at least one instance, it was reported that heavy duty shock absorbers did not rectify the poorer handling condition. The effects, whether good or bad, are most noticeable at high speed (over 60 mph). This additional weight increases the vehicular weight by from 5 to 10% and decreases the 1100-lb. load carrying capacity of most sedans by 17%. This additional weight will undoubtedly increase wear and tear on the vehicle chassis, and particularly such items as shock absorbers, tires, and brakes.

In an effort to obtain in-service operational experience on the effectiveness of water-filled bumpers, a questionnaire, referred to above, was sent to all users who operated fleets of vehicles employing the bumpers. A total of 153 questionnaires was distributed and 87 were returned. A copy of this questionnaire is attached as Exhibit 2. The returned questionnaire provided information on more than 130 accidents. In more than 90% of these accidents, the water-filled bumper was considered by its users to be effective in reducing, at least to some extent, the injuries and/or property damage sustained. The relative vehicle impact velocity for most of these accidents was less than 30 mph. However, a few of the accidents, based on relative impact velocities reported, were very severe. In one instance, a stationary vehicle was hit from the rear by a vehicle traveling 60 mph. Although it was reported that the bumper reduced injuries and property damage, the extent of this reduction was probably very minimal. The same results were reported for a rear-end accident in which a vehicle traveling 80 mph struck a vehicle traveling 25 mph. Again, the amount of damage and injury prevention attributal to the plastic bumper was probably very minimal.

The over-all customer satisfaction with the water-filled plastic bumper varied from enthusiastic endorsement to equally enthusiastic unfavorable comments. Most of the firms having fleet experience were taxi cab companies. The plastic bumpers may be a significant safety improvement for these taxi cabs due to the type of accident cabs are most often involved in (low speed, fender-bender type in conjested bumper-to-bumper traffic) and the number of accidents cabs are involved in (3.4 accidents per cab year in one instance). These cab companies have, in some instances, reported accident cost savings as high as 50%. In one instance, it was reported that the installation of the plastic bumpers was paid for in approximately a 6 month period.

Thirty-two percent of the organizations responding to the questionnaire indicated that water level maintenance of the plastic bumper was a problem. It is conceivable that some minor impacts may result in ejected water that is not immediately noticeable. In one instance, it was reported that a $300 repair bill was incurred because the water-filled bumper was unknowingly empty at the time of impact, a condition that probably resulted in greater damage to body and fender(s) than would have occurred with a steel bumper.

In summary, the cost of installation of water-filled plastic bumpers on State-owned vehicles does not appear to be economically justifiable at this time. Insurance companies, with rare exceptions, are not currently giving rate reductions for the installation of the bumpers. Also, the bumper's effectiveness is dependent, to a great degree, on a large number of variables, the ideal combination of which is highly unlikely to occur in average use of State-owned vehicles. Until decreased insurance costs to the State become available and/or it becomes reasonable to assume that more than a 65% reduction in property damage to State-owned vehicles can be realized, water-filled bumpers cannot be economically justified. Furthermore, considering the physical principals involved, it seems evident at this point, apart from some unanticipated revolutionary development of a highly efficient energy absorbing media, that the damage reduction affected by any vehicular bumper in all but ideal collision conditions at low speeds will remain minimal.

VI. REFERENCES

1. Performance of Water-Filled Plastic Bumpers in Full-Scale Automobile Collisions, Brigham Young University, Department of Mechanical Engineering, December 1, 1967.

2. Tests of Water-Filled Plastic Bumpers in Rear-End Collisions, Dr. Charles Y. Warner, Brigham Young University, Department of Mechanical Engineering, Research Report RSCB-3, March 15, 1969.

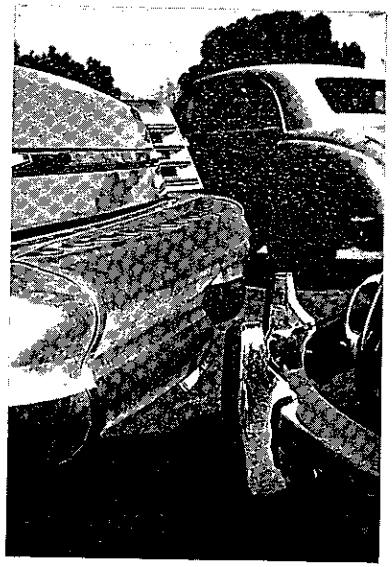
3. Society of Automotive Engineers, Inc., Technical Report J681a, 1968.

4. State of California Personnel Statistics - Table 92 - Semi-Annual Report, State Driver Accidents, July - December 1967.

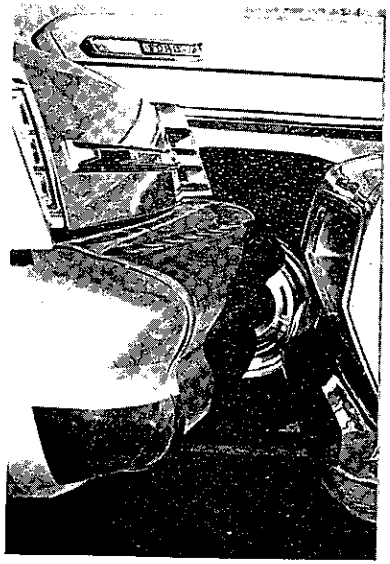
5. State of California Personnel Statistics - Table 92 - Semi-Annual Report, State Driver Accidents, January - June, 1968.

6. State of California Department of Motor Vehicles Statement of Transactions and Total Fees Collected, November 1968.

7. State of California Department of Motor Vehicles Statement of Transactions and Total Fees Collected, Special 1968 Early Renewal Report dated December 1967.



1967 CHRYSLER -
1969 VW



1967 CHRYSLER -
1968 BARACUDA

1967 CHRYSLER -
1969 CHEV.

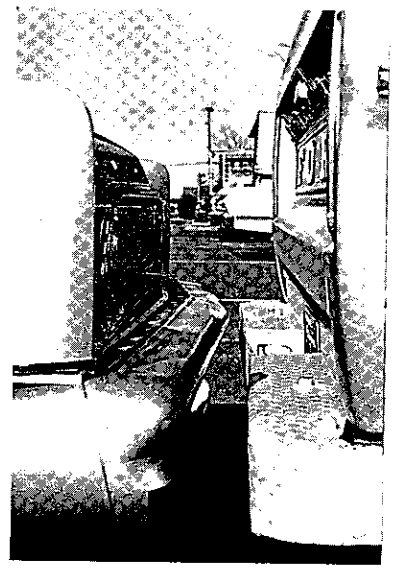
1967 CHRYSLER -
1967 FORD P.U.

STEEL BUMPER INTO PLASTIC BUMPER

1969 VW -
1967 CHRYSLER

1968 MUSTANG -
1967 CHRYSLER

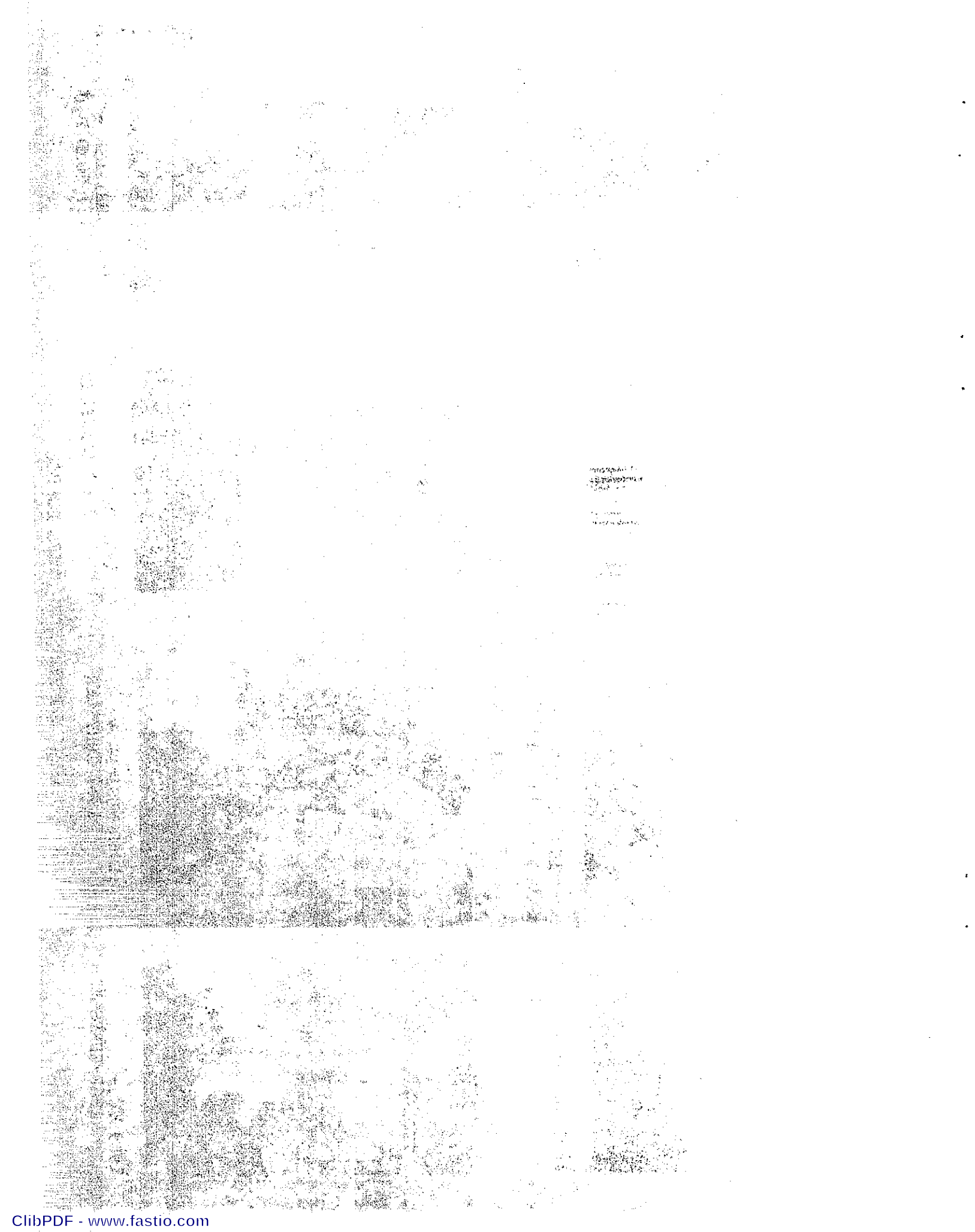
1967 OLDS -
1967 CHRYSLER



1967 CHRYSLER -
1967 FORD P.U.

PLASTIC BUMPER INTO STEEL BUMPER

Exhibit 1



STATE OF CALIFORNIA—TRANSPORTATION AGENCY
RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

File: Project 646443

Gentlemen:

The Legislative Assembly of the State of California, in the interest of promoting highway safety and economy in State government, is considering the safety and economic benefits of certain water-filled highway safety devices. Your assistance is needed in a survey we are conducting to appraise the performance of water-filled bumpers as partial fulfillment of the requests made in the following resolution that was passed during the 1968 Legislative Session:

House Resolution No. 203

Relating to water-filled safety devices for vehicles and freeways.

Resolved by the Assembly of the State of California, That the Transportation Agency, in cooperation with the Department of General Services, is requested to conduct an investigation concerning the safety and economic benefits of water-filled bumpers for vehicles and water-filled barriers for obstacles adjacent to freeways, with reference to be made, to the greatest extent possible, to research efforts being done by other agencies concerning these subjects; and be it further

Resolved, That the Transportation Agency, in cooperation with the Department of General Services, is requested to prepare and submit a preliminary report to the Legislature no later than March 30, 1969, concerning the results of the investigation conducted, including in its report the feasibility of putting water-filled bumpers on state-owned vehicles.

This department has been delegated the responsibility of obtaining the necessary information and assembling the specified report for the Legislature. Therefore, your cooperation and prompt attention to the attached questionnaire will be very much appreciated. A self addressed envelope is enclosed for your convenience. Thank you.

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

WHA/mw
Attach.

QUESTIONNAIRE ON WATER-FILLED BUMPERS

1. How many vehicles in use by your firm or organization are equipped with water-filled bumpers?

   ☐ Less than 10
   ☐ 10 - 30
   ☐ 31 - 50
   ☐ More than 50

2. On what types of vehicles are your bumpers installed? (Please indicate approximate number of each if more than one type.)

   _____ Sedan - compact
   _____ Sedan - standard
   _____ P.U. truck
   _____ Light van
   _____ Other - please specify _____

3. How long have these bumpers been in use by your firm?

   ☐ Less than 6 months
   ☐ 6 - 12 months
   ☐ 13 - 24 months
   ☐ More than 24 months

4. In your opinion, did the bumpers alter the handling characteristics or maneuverability of the vehicles on which they were installed?

   ☐ Yes (If yes, was handling improved? Yes ____ No ____)
   ☐ No

5. Are you satisfied with the durability of the bumpers?

   ☐ Yes
   ☐ No

6. Are you satisfied with the appearance of the bumpers?

   ☐ Yes
   ☐ No

7. Is water level maintenance a problem?

   ☐ Yes
   ☐ No

8. Do you have any accident experience with vehicles on which bumpers were installed?

   ☐ Yes (If yes, please fill in the attached Table A)
   ☐ No

9. Has your vehicular insurance rate been lowered because of your installation of the water bumpers?

☑ Yes (PD & PL _____ Collision _____ Both _____)
☐ No

10. Has the bumper performance to date been economically justified?

☑ Yes
☐ No

11. Would you suggest that these bumpers be installed on State-owned vehicles?

☐ Yes
☐ No

12. We welcome any comments you would like to offer pertaining to the effectiveness of these bumpers.

Name of firm or organization (optional)

_____

TABLE A

Accident No.	Vehicle Speed MPH		Other Vehicle Equipped with Water Bumper		Type of Vehicle[A]		Type of Collision[B]	Did the Water Bumper(s) Prevent or Reduce Injuries?		Did the Water Bumper(s) Prevent or Reduce Property Damage?	
	Yours	Other	Yes	No	Yours	Other		Yes	No	Yes	No

A: Type Description

1 Sedan - compact
2 Sedan - standard
3 P.U. truck
4 Light van
5 Other - please specify

B: Vehicle shown represents your vehicle.